Models and Methods in Mobile Edge Computing Systems

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Outline

1. Models
   - User Mobility
   - Path Selection and Rate Allocation
   - Service Composition and Selection
   - Utility Maximization or Penalty Minimization in Networks
   - Combinations of the Above Contents in Different Scenarios

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2. Methods
   - Evolutionary Algorithms
   - Lyapunov Optimization
   - Stochastic Programming
   - Perturbation Theory
   - Optimization Methods for Machine Learning
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3. Future Works

Outline

Different Mobilities Models (ad hoc networks)

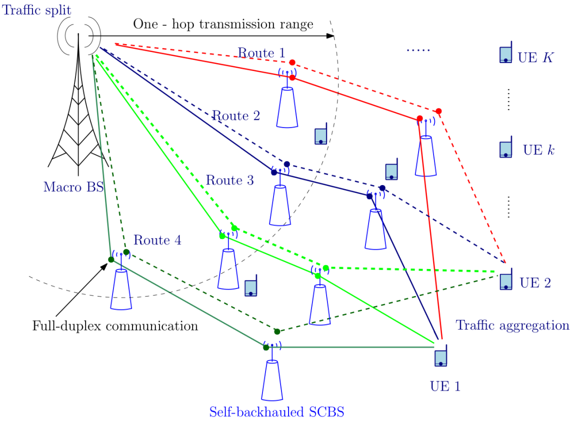
- Entity Mobility Models
  - random work
  - random waypoint
  - random direction
  - a boundless simulation Area
  - Gauss-Markov
  - a probabilistic version of random walk
  - city section mobility model
- Group Mobility Models
  - exponential correlated random mobility
  - column mobility model
  - nomadic commuity mobility model
  - purse mobility model
  - reference point group mobility model

Put User Mobility in Different Scenarios

- Integrate with Composite Services (mobility model grid)
- In (5G) Cell Networks (consisting of macro and small cell BSs)
- Fixed User's Path
  - only *QoMN* is changing
  - only channel power gain is changing (because of distances)
  - other variables in different networks...

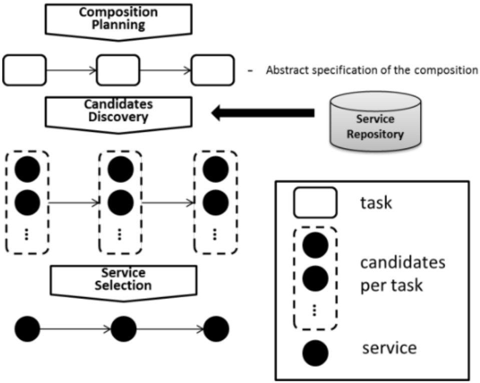
In Self-Backhauled mmWave Networks

- Select the Best Paths and Allocate Rates over these Paths



Service Selection

- Mobility-Enabled Service Selection from Candidates



Service Composition

- Take Execution Sequence into Consideration (How?)
- The Amount of Input/Output for each Tasks are Different
- Parallel Tasks
  - each parallel task can be represented by a task buffer
  - each task buffer can be executed simultaneously **in order**
  - what about the tasks were offloaded to different MEC servers?

Penalty Minimization in Stochastic Networks

Yuyi Mao's papers* are inundated with this kind of model!

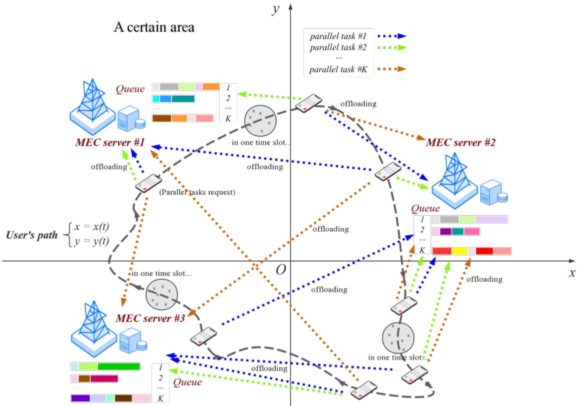
- Match with Lyapunov Optimization Methods
  - Construct Virtual Queues for Constraints
  - Replace the Original Problem with a Deterministic one
  - Solve the Approximate-Convex Problem with **Ingenious Mathematic Tricks**
- Utilize Lagrange Methods and KKT Conditions
- Performence Analysis $(O(V), O(\frac{1}{V}))$

Apperently Yuyi Mao acquires proficiency in Michael. J. Neely's book: *Stochatsic Network Optimization with Application to Communication and Queueing Systems*

Utility Maximization in Stochastic Networks

There has no significant difference between $-\bar{U}$ and $\bar{p}$.
But if we comprehend Neely's book **thoroughly**, we can find that **there are many variations and all of them can be utilized to form a new model!**

Our 1st Model



Our 2nd Model

I haven't drawn the schematic diagram of the model. :-(

Outline

Traditional Heuristic Algorithms

- Swarm Intelligence
- Tabu Search
- Simulated Annealing
- Artificial Neural Networks
- Population-based Algorithms
  - genetic algorithm
  - particle swarm optimization
  - negative selection algorithm
  - learning-teaching-based optimization
  - ...
- Too many of Them...

Model-Based Derivative-Free Methods

- **Zeroth-order optimization**

Derivative-free optimization/black-box optimization does not rely on the gradient of the objective function, but instead, learns from samples of the search space. It is suitable for optimizing functions that are nondifferentiable, with many local minima, or even unknown but only testable.
(These works are contributed by Yang Yu from **LAMDA Group, Nanjing Univerity**. Code can be found at Link)

Standard Lyapunov optimization

A trump card for stochastic optimization problems!

- Virtual Queues
- Drift-Plus-Penalty Expression
- Approximate Scheduling
- Performance Analysis
  - average penalty analysis
  - average queue size analysis
- Delay Tradeoffs

Extensions on Lyapunov Optimization

Each of these extensions can construct many models!

1. Extensions to Variable Frame Length Systems (Dynamic Optimization and Learning for **Renewal Systems**)
2. Combination with **Lagrange Multipliers**
3. Network Utility Maximization over Partially Observable **Markovian Channels**
4. Under **Non-Convex Problems** (Greedy primal-dual algorithm)

Two-Stage Stochastic Programming

- Scenario construction
- Monte Carlo techniques (**SAA method**)
- Evaluation Candidate Solutions (**measure the optimality gap between the optimal value and the estimated value**)

Multi-Stage Stochastic Programming

Take the "SAA" paper for example: (This paper can be found at ▸ Link)

- Scenario construction
- Monte Carlo techniques (**SAA method**)
- The Implemetation of algorithms in this paper can be found at ▸ Link

Perturbation Theory

Comprise mathematical methods for finding an approximate solution to a problem.

- Time-Independent Perturbation Theory
  - Non-degenerate Case
  - Degenerate Case
  - The Stark Effect
- Time-Dependent Perturbation Theory
  - Review of Interaction Picture
  - Dyson Series
  - Fermi's Golden Rule

Perturbation Theory always help Lyapunov Optimization work better (read Neely's book).

Optimization for Machine Learning

What we talk about here are numerical optimization algorithms in the context of large-scale machine learning applications.

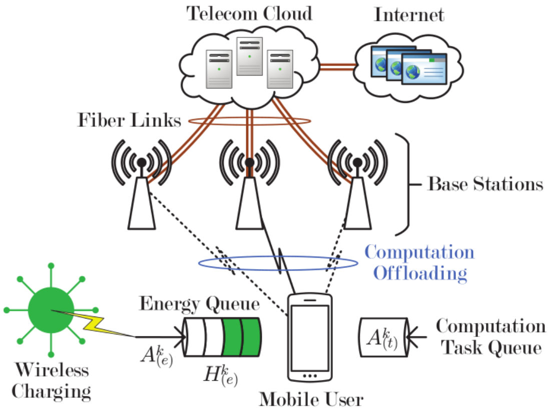
- Gradient Descend Methods (in batch)
- Stochastic Gradient Descend Methods
- Noise Reduction and Second-Order Methods
- Other Popular Methods
  - Gradient Methods with Momentum
  - Accelerated Gradient Methods
  - Coordinate Descent Methods
- Methods for Regularized Models

Deep Neural Networks

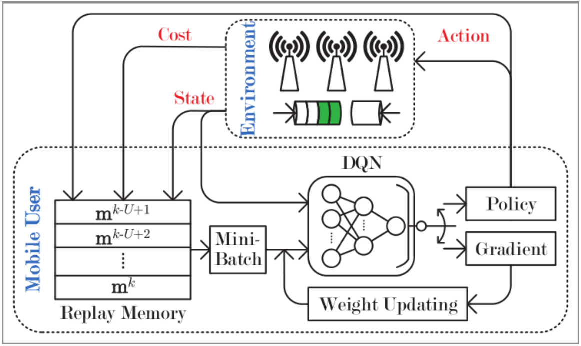
Typical method is **Deep Q-Network** (a combination of DNN and Reinforcement Learning).

- Take the paper "Performance Optimization in Mobile-Edge Computing via Deep Reinforcement Learning" for example: (which can be found at ▸ Link)

Deep Neural Networks



Deep Neural Networks



Proposed Algorithms for Our Model

Didn't finish yet. :-(

Outline

Further Work

- Combinations of different Models and Methods
- Models should be Associated with the **Reality**
- **Thoroughly Understand** Neely's book and *Convex Optimization* by Stephen Boyd